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Neusinger et al.

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(54) **UPMIXER, METHOD AND COMPUTER PROGRAM FOR UPMIXING A DOWNMIX AUDIO SIGNAL**

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(58) **Field of Classification Search**
CPC H04R 5/00; G10L 19/00
USPC 381/17, 22–23, 119; 704/500–501, 704/E19.001
See application file for complete search history.

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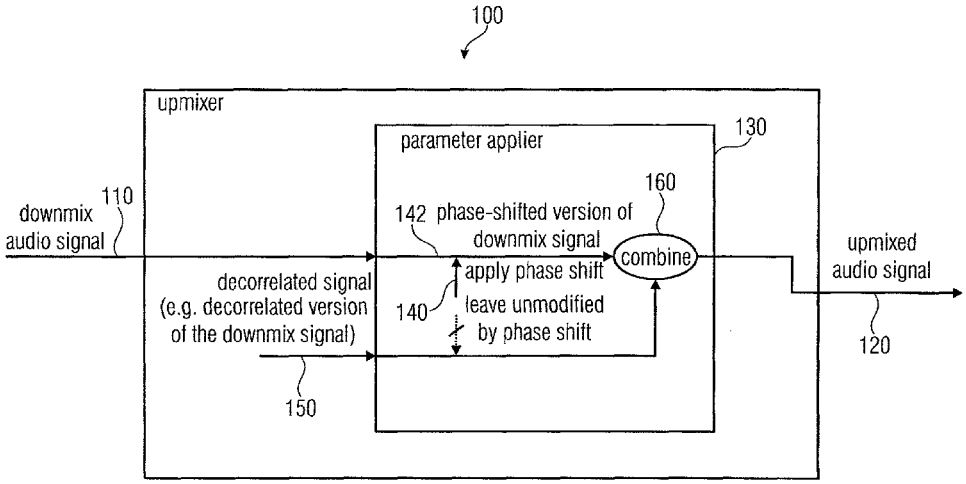
(57) **ABSTRACT**

An upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels includes a parameter applier configured to apply upmixing parameters to upmix the downmix audio signal in order to obtain the upmixed audio signal. The parameter applier is configured to apply a phase shift to the downmix audio signal to obtain a phase-shifted version of the downmix audio signal, while leaving a decorrelated signal unmodified by the phase shift. The parameter applier is further configured to combine the phase-shifted version of the downmix audio signal with the decorrelated signal to obtain the upmixed audio signal.

17 Claims, 5 Drawing Sheets



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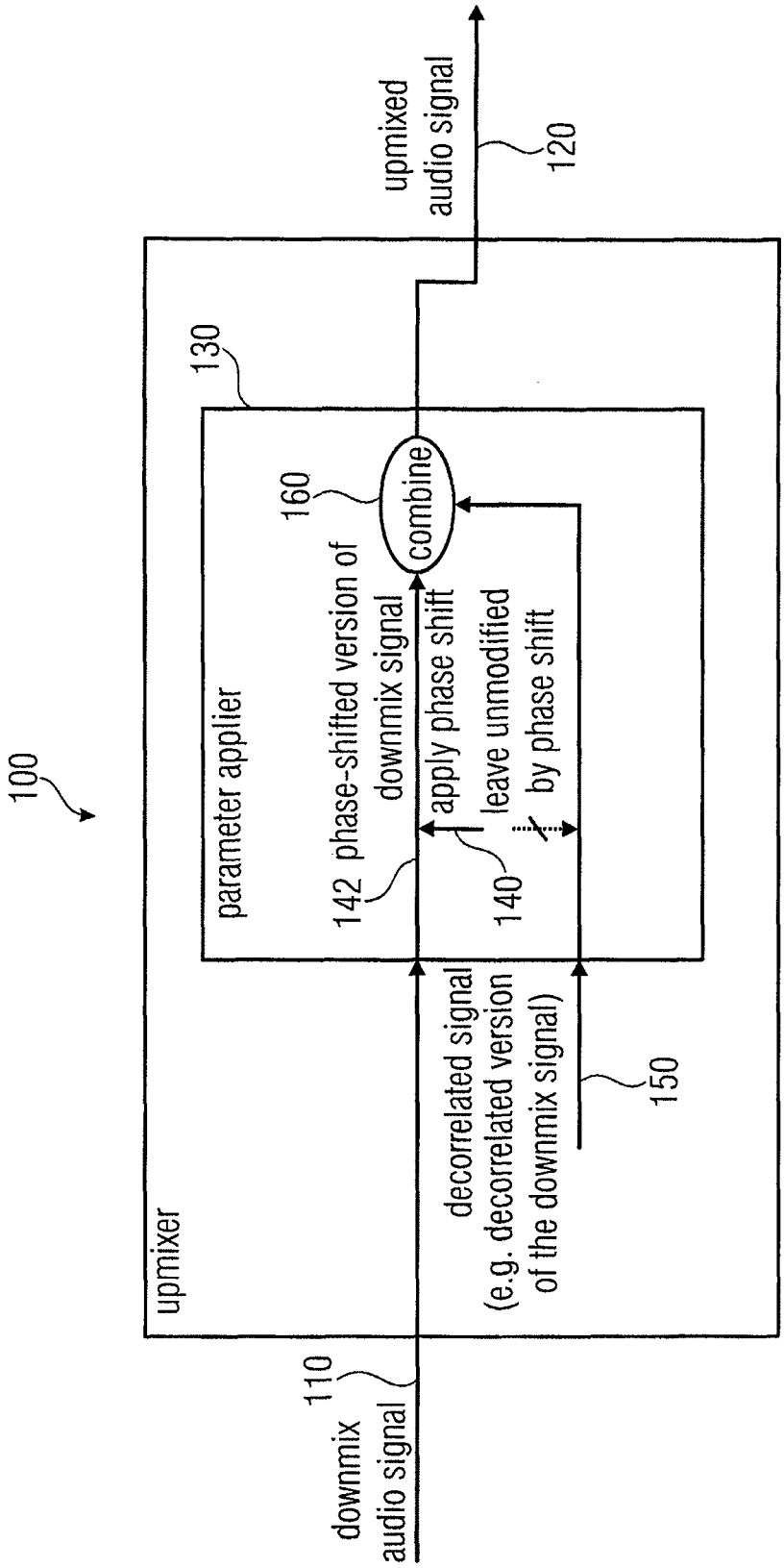
100
upmixer
downmix audio signal
110
decorrelated signal (e.g. decorrelated version of the downmix signal)
150
parameter applier
130
142 phase-shifted version of downmix signal
apply phase shift
140
leave unmodified by phase shift
160
combine
upmixed audio signal
120

FIG 1

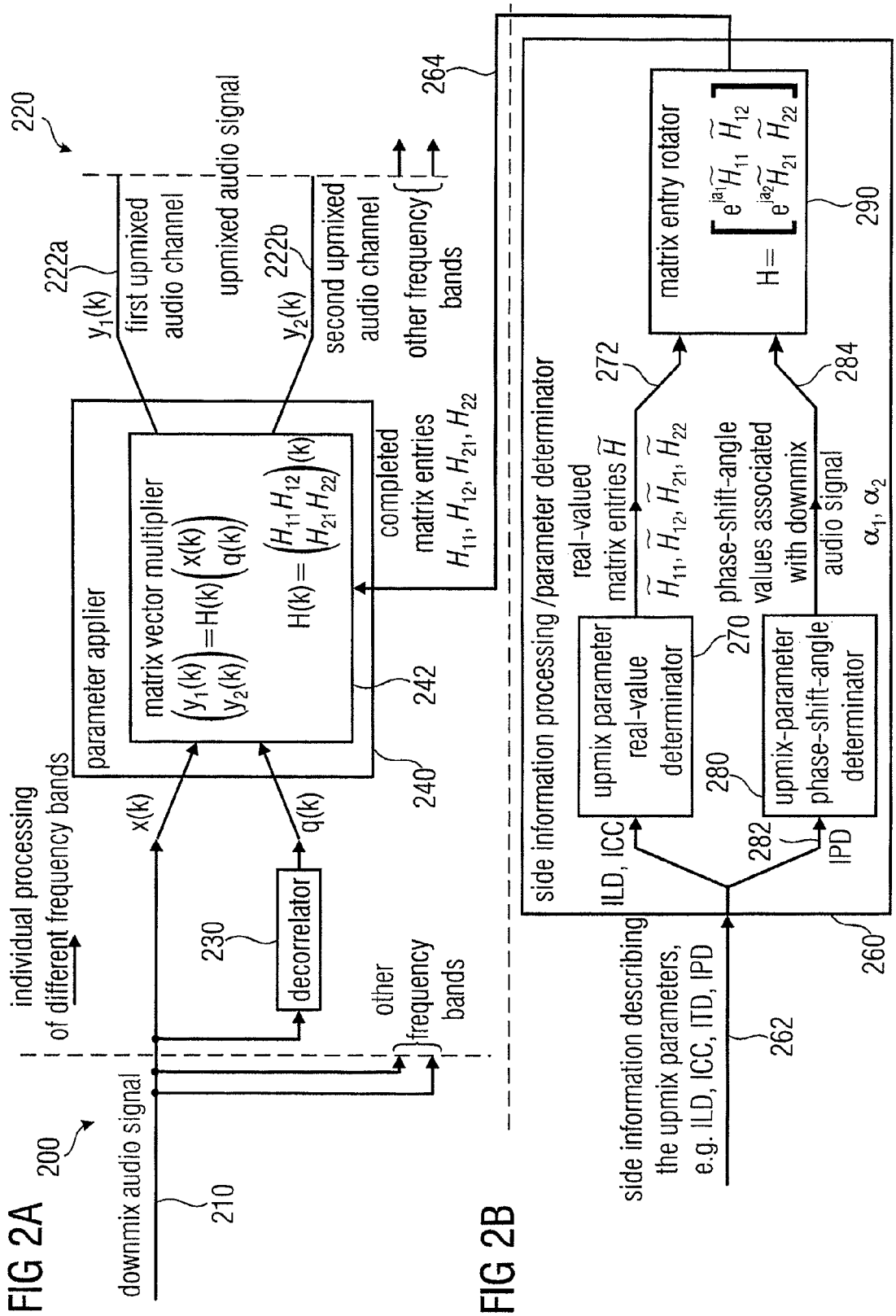
FIG 2A
200
downmix audio signal
210
individual processing of different frequency bands
other frequency bands
x(k)
q(k)
230
decorrelator
parameter applier
matrix vector multiplier
$\begin{pmatrix} y_1(k) \\ y_2(k) \end{pmatrix} = H(k) \begin{pmatrix} x(k) \\ q(k) \end{pmatrix}$
$H(k) = \begin{pmatrix} H_{11} H_{12} \\ H_{21} H_{22} \end{pmatrix}(k)$
240
242
completed matrix entries
$H_{11}, H_{12}, H_{21}, H_{22}$
220
222a
$y_1(k)$
first upmixed audio channel
upmixed audio signal
222b
$y_2(k)$
second upmixed audio channel
other frequency bands
264
FIG 2B
side information processing /parameter determinator
side information describing the upmix parameters, e.g. ILD, ICC, ITD, IPD
262
260
ILD, ICC
upmix parameter real-value determinator
280
270
real-valued matrix entries $\tilde{H}$
$\tilde{H}_{11}, \tilde{H}_{12}, \tilde{H}_{21}, \tilde{H}_{22}$
272
IPD
upmix-parameter phase-shift-angle determinator
282
phase-shift-angle values associated with downmix audio signal
α_1, α_2
284
matrix entry rotator
$H = \begin{bmatrix} e^{j\alpha_1} \tilde{H}_{11} & \tilde{H}_{12} \\ e^{j\alpha_2} \tilde{H}_{21} & \tilde{H}_{22} \end{bmatrix}$
290

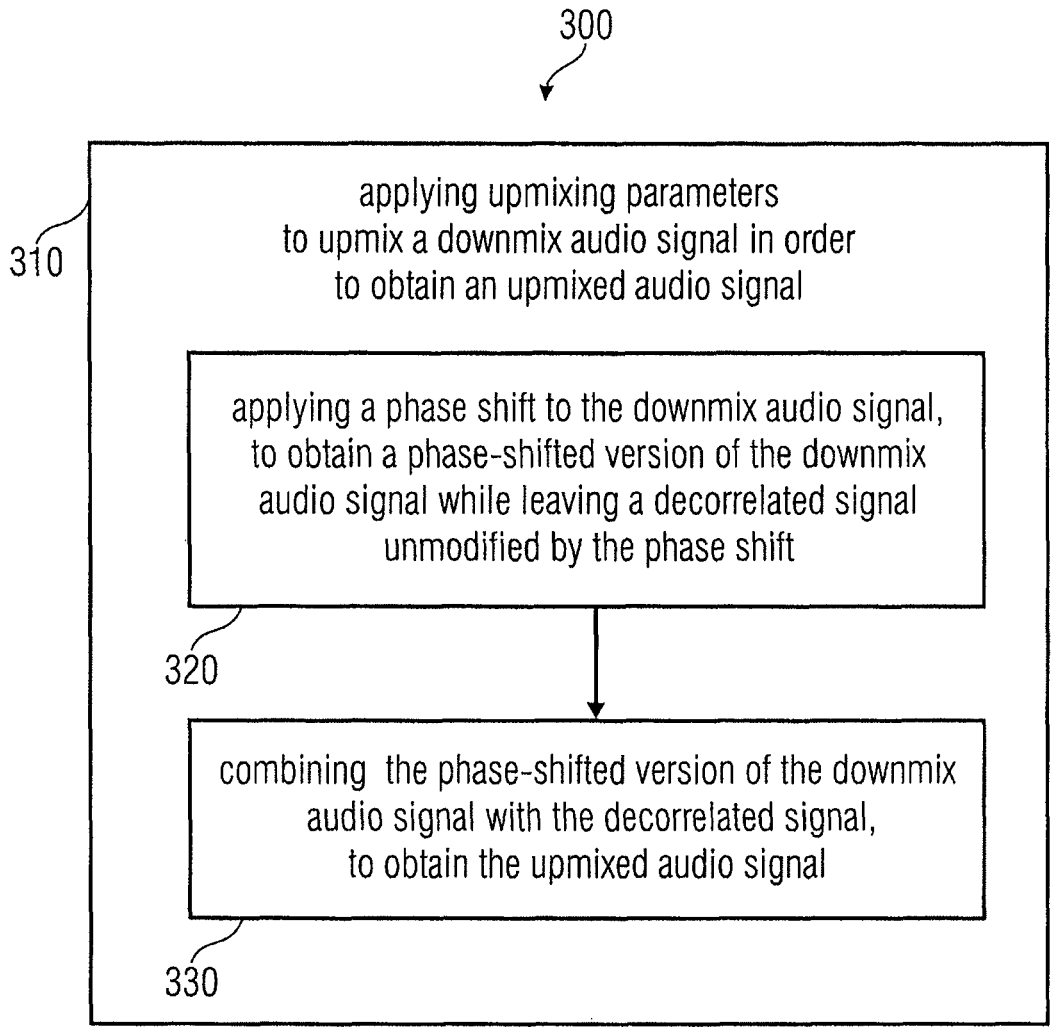
300
310
applying upmixing parameters to upmix a downmix audio signal in order to obtain an upmixed audio signal
applying a phase shift to the downmix audio signal, to obtain a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift
320
combining the phase-shifted version of the downmix audio signal with the decorrelated signal, to obtain the upmixed audio signal
330

FIG 3A

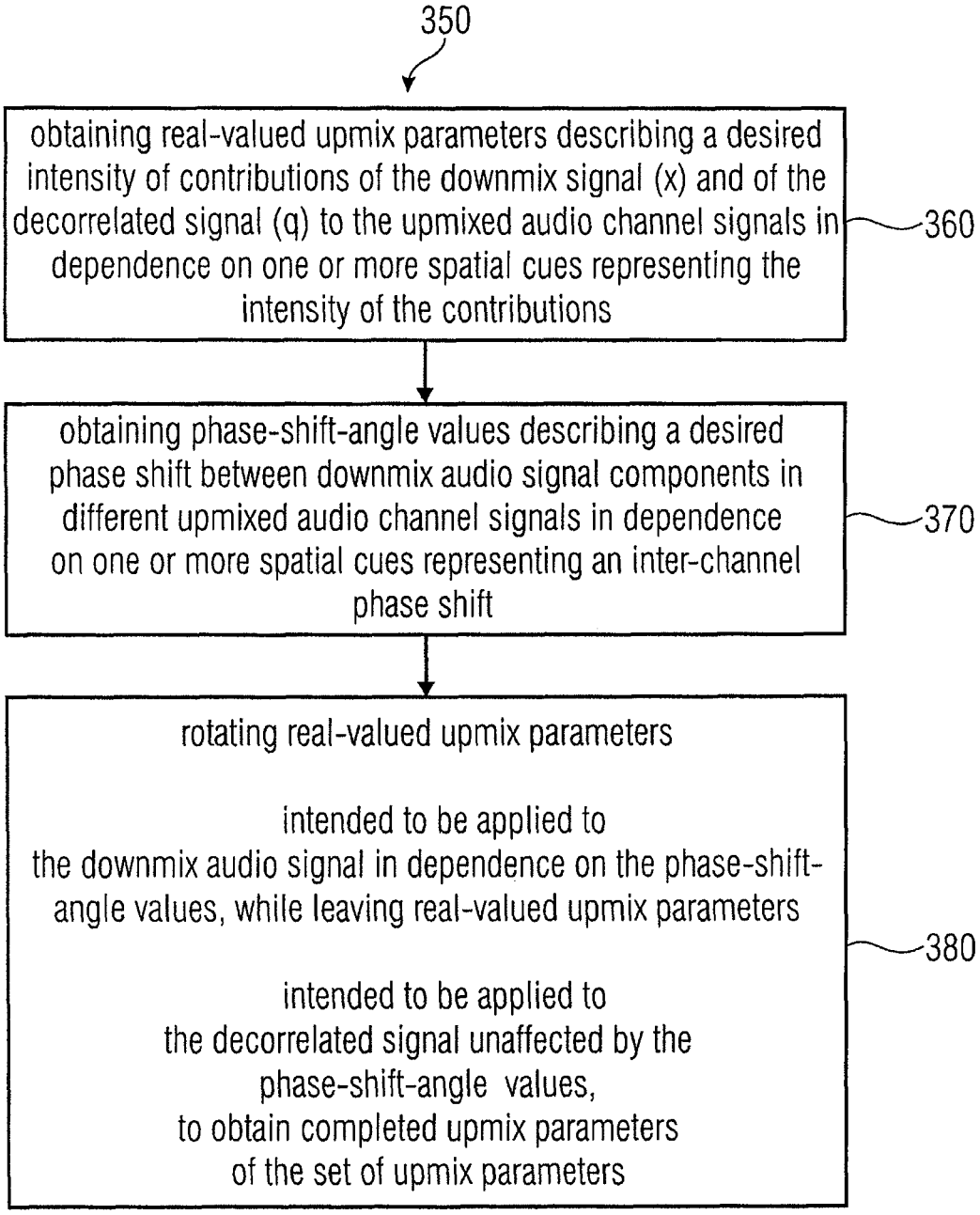
350
obtaining real-valued upmix parameters describing a desired intensity of contributions of the downmix signal (x) and of the decorrelated signal (q) to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contributions
360
obtaining phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase shift
370
rotating real-valued upmix parameters
intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters
intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values,
to obtain completed upmix parameters of the set of upmix parameters
380

FIG 3B

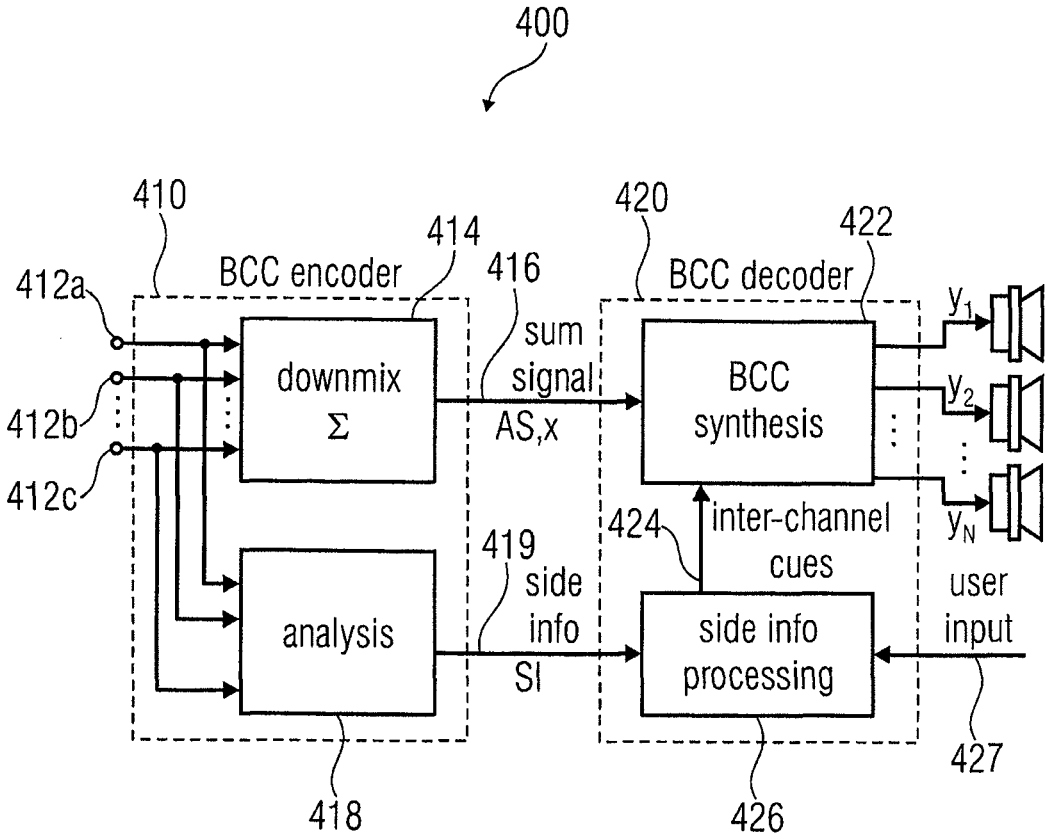
400
410
BCC encoder
414
416
420
BCC decoder
422
412a
412b
412c
downmix
Σ
sum
signal
AS,x
BCC
synthesis
y_1
y_2
y_N
424
inter-channel
cues
419
side
info
SI
analysis
side info
processing
user
input
427
418
426

FIG 4

UPMIXER, METHOD AND COMPUTER PROGRAM FOR UPMIXING A DOWNMIX AUDIO SIGNAL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of copending International Application No. PCT/EP2010/050287, filed Jan. 12, 2010, which is incorporated herein by reference in its entirety, and additionally claims priority from U.S. Application No. 61/147,810, filed Jan. 28, 2009, and from European Application No. EP 09012285.4, filed Sep. 28, 2009, which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

Embodiments according to the invention are related to an upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels. Some embodiments according to the invention are related to a method and to a computer program for upmixing a downmix audio signal.

Some embodiments according to the invention are related to an improved phase processing for parametric multi-channel audio coding.

In the following, a short overview will be given and the context of the invention will be described. Recent developments in the area of parametric audio coding delivers techniques for jointly coding a multi-channel audio (e.g. 5.1) signal into one (or more) downmix channels plus a side information stream. These techniques are, for example, known as Binaural Cue Coding, Parametric Stereo, MPEG Surround, etc.

A number of publications describe the so-called "Binaural Cue Coding" parametric multi-channel coding approach, for example references [1], [2], [3], [4] and [5].

"Parametric Stereo" is a related technique for the parametric coding of a two-channel stereo signal based on a transmitted mono signal plus parameter side information. For details, reference is made to references [6] and [7].

"MPEG Surround" is an ISO (International Standardization Organization) standard for parametric multi-channel coding. For details, reference is made to reference [8].

These techniques are based on transmitting the relevant perceptual cues for human's spatial hearing in a compact form to the receiver together with the associated mono or stereo downmix-signal. Typical cues can be inter-channel level differences (ILD), inter-channel correlation or coherence (ICC) as well as inter-channel time differences (ITD) and inter-channel phase differences (IPD).

These parameters are transmitted in a frequency and time resolution adapted to the human's auditory resolution.

To recreate the properties of the original signal, the decoder may produce one or more decorrelated versions of the transmitted downmix signal. Additionally, a phase rotation of the output signals may be performed in the decoder to restore the original inter-channel phase relation.

Example Binaural Cue Coding System of FIG. **4**

In the following, a generic binaural cue coding scheme will be described taking reference to FIG. **4**. FIG. **4** shows a block schematic diagram of a binaural cue coding transmission system **400**, which comprises a binaural cue coding encoder **410** and a binaural cue coding decoder **420**. The binaural cue coding encoder **410** may for example receive a plurality of audio signals **412***a*, **412***b*, and **412***c*. Further, the binaural cue coding encoder **410** is configured to downmix the audio input signals **412***a*-**412***c* using a downmixer **414** to obtain a downmix signal **416**, which may for example be a sum signal. Further, the binaural cue coding encoder **410** may be configured to analyze the audio input signals **412***a*-**412***c* using an analyzer **418** to obtain the side information signal **419**. The sum signal **416** and the side information signal **419** are transmitted from the binaural cue coding encoder **410** to the binaural cue coding decoder **420**. The binaural cue coding decoder **420** may be configured to synthesize a multi-channel audio output signal comprising, for example, audio channels **y1**, **y2**, . . . , y_N on the basis of the sum signal **416** and inter-channel cues **424**. For this purpose, the binaural cue coding decoder **420** may comprise binaural cue coding synthesizer **422** which receives the sum signal **416** and the inter-channel cues **424**, and provides the audio signals **y1**, **y2**, . . . , y_N. The binaural cue coding decoder **420** further comprises a side information processor **426** which is configured to receive the side information **419** and, optionally, a user input **427**. The side information processor **426** is configured to provide the inter-channel cues **424** on the basis of the side information **419** and the optional user input **427**.

To summarize, the audio input signals are analyzed and downmixed in the BCC encoder **410**. The sum signal plus the side information is transmitted to the BCC decoder **420**. The inter-channel cues are generated from the side information and local user input. The binaural cue coding synthesis generates the multi-channel audio output signal.

For details, reference is made to the articles "Binaural Cue Coding Part II: Schemes and applications," by C. Faller and F. Baumgarte (published in: IEEE Transactions on Speech and Audio Processing, vol. 11, no. 6, November 2003).

Discussion of the Conventional Approaches

In the above-described approaches, it is difficult to appropriately control the inter-channel relation.

Accordingly, it is desirable to create a concept for upmixing a downmix signal, which provides a good accuracy with respect to an inter-channel correlation.

SUMMARY

According to an embodiment, an upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels may have: a parameter applier configured to apply upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal, wherein the parameter applier is configured to apply a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift, and to combine the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal.

According to another embodiment, an apparatus for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio channels may have: an upmix parameter real-value determinator configured to achieve real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of a decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contributions;

an upmix-parameter phase-shift-angle determinator configured to achieve one or more phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing

an inter-channel phase difference; and an upmix parameter rotator configured to rotate real-valued upmix parameters provided by the upmix parameter real-value determinator and intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters provided by the upmix parameter real-value determinator and intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values, to achieve completed upmix parameters of the set of upmix parameters.

According to another embodiment, a method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels may have the steps of: applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal; wherein applying upmixing parameters includes applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and wherein applying the upmixing parameters includes combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal.

According to another embodiment, a method for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio signals may have the steps of: achieving real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of the decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contribution; achieving phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase difference; and rotating real-valued upmix parameters intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values, to achieve completed upmix parameters of the set of upmix parameters.

Another embodiment may have a computer program for performing a method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, which method may have the steps of: applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal; wherein applying upmixing parameters includes applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and wherein applying the upmixing parameters includes combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal, when the computer program runs on a computer.

Another embodiment may have a computer program for performing a method for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio signals, which method may have the steps of: achieving real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of the decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contribution; achieving phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase difference; and rotating real-valued upmix parameters intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values, to achieve completed upmix parameters of the set of upmix parameters, when the computer program runs on a computer.

Embodiments according to the invention create an upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels. The upmixer comprises a parameter applier configured to apply upmixing parameters to upmix the downmix audio signal in order to obtain the upmixed audio signal. The parameter applier is configured to apply a phase shift to the downmix audio signal, to obtain a phase-shifted version of the downmix audio signal, while leaving a decorrelated signal unmodified by the phase shift. The parameter applier is also configured to combine the phase-shifted version of the downmix audio signal with the decorrelated signal to obtain the upmix signal.

Some embodiments according to the invention are based on the finding that an inter-channel correlation between different upmixed audio signals is degraded by applying a phase shift (for example, a time-variable phase shift, which depends on spatial cues) to the decorrelated signal. Accordingly, it has been found that it is desirable to leave the decorrelated signal unmodified by the phase shift, which is applied to the downmix signal in order to obtain an appropriate inter-channel phase shift between different of the upmixed audio channels.

Accordingly, the improved phase processing according to the invention contributes to preventing incorrect output inter-channel correlation (of the upmixed audio channels), which would be caused by a phase-shifting of the decorrelated signal part.

In an advantageous embodiment, the upmixer is configured to obtain the decorrelated signal such that the decorrelated signal is a decorrelated version of the downmix audio signal. Thus, the decorrelated signal can easily be obtained from the downmix signal. However, in some other embodiments, different concepts may be used for obtaining the decorrelated signal. In a very simple solution, a noise signal may be used as the decorrelated signal.

In an advantageous embodiment, the upmixer is configured to upmix the downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio channels. In this case, the parameter applier is configured to apply the upmixing parameters to upmix the downmix audio signal using the decorrelated signal in order to obtain a first upmixed audio channel signal and a second upmixed audio channel signal. The parameter applier is configured to apply a time-variant phase shift to the downmix audio signal to obtain at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other. The parameter applier is also configured to combine the at least two versions of the downmix audio signal with the decorrelated signal to obtain the at least two upmixed audio channel signals such that the decorrelated signal remains unaffected by the time-variant phase shift. Accordingly, multiple channel signals of the upmixed audio signal can be obtained, wherein the decorrelated signal portions within the multiple upmixed channels (of the upmixed audio signal) are unaffected by relative phase shifts introduced between the correlated signal portions thereof. Consequently, the inter-channel correlation between the upmixed audio channels can be controlled with good precision.

In an embodiment, the parameter-applier is configured to combine the at least two versions of the downmix audio signal with the decorrelated signal such that a signal portion of the first upmixed audio channel signal representing the decorrelated signal and a signal portion of the second upmixed audio channel signal representing the decorrelated signal are in a temporally constant phase relationship, for example in-phase or 180° out-of-phase with respect to each other. Consequently, the signal portions representing the decorrelated signal can effectively serve to adjust the correlation of the upmixed audio channel signals. In contrast, if the signal portions representing the decorrelated signal would be arbitrarily or variably phase-shifted with respect to each other in the different upmixed audio channel signals, an adjustment of the desired inter-channel correlation would be degraded or even prevented.

In an embodiment according to the invention, the parameter-applier is configured to obtain the at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other before combining the at least two versions of the downmix audio signal (comprising the time-variant phase shift with respect to each other) with the decorrelated signal, which decorrelated signal is left unaffected by the time-variant phase shift. By applying the time-variant phase shift before combining the result thereof with the decorrelated signal, the decorrelated signal is left unaffected by the time-variant phase shift. Consequently, the correlation characteristics of the resulting upmixed audio channel signals can be precisely adjusted.

In an embodiment according to the invention, the upmixer comprises a parameter determinator configured to determine the phase shift to be applied to the downmix audio signal on the basis of an inter-channel phase difference parameter. Accordingly, the phase shift is adapted to fit the desired human hearing impression.

In an embodiment according to the invention, the parameter-applier comprises a matrix-vector multiplier configured to multiply an input vector representing one or more samples of the downmix signal and one or more samples of the decorrelated signal with a matrix comprising matrix entries representing upmix parameters. The multiplication is performed to obtain, as a result, an output vector representing one or more samples of a first upmixed audio signal channel and one or more samples of a second upmixed audio signal channel. The upmixer comprises a parameter determinator configured to obtain the matrix entries on the basis of spatial cues associated with the downmix audio signal. The parameter determinator is configured to apply a time-varying phase rotation only to matrix entries to be applied to the one or more samples of the downmix signal, while leaving a phase of matrix entries to be applied to the one or more samples of the decorrelated signal unaffected by the time-varying phase rotation. By leaving some of the matrix entries, namely those which are applied to the decorrelated signal, unaffected by the time-varying phase rotation, an efficient implementation of the inventive concept can be obtained. The computational effort involved can be reduced by having some matrix elements, which comprise a fixed phase value (or which, for example, may be real-valued independent from the spatial cues). In addition, the determination of the matrix entries is naturally relatively simple if the phase values are constant.

In an embodiment, the matrix-vector multiplier is configured to receive the samples of the downmix audio signal and the samples of the decorrelated signal in a complex-valued representation. In addition, the matrix-vector multiplier is configured to apply complex-valued matrix entries to the input vector in order to apply a phase shift and to obtain the samples of the upmixed audio signal channels in a complex-valued representation. In this case, the parameter determinator is configured to compute real values or magnitude values of the matrix entries on the basis of inter-channel level difference parameters and/or inter-channel correlation parameters and/or inter-channel coherence parameters (or inter-channel correlation or coherence parameters) associated with the downmix audio signal. In addition, the parameter determinator is configured to compute phase values of matrix entries to be applied to the one or more samples of the downmix signal on the basis of inter-channel phase difference parameters associated with the downmix audio signal. Additionally, the parameter determinator is configured to apply a complex rotation to the magnitude values of the matrix entries to be applied to the one or more samples of the downmix signal in dependence on the corresponding phase values to obtain the matrix entries to be applied to the one or more samples of the downmix signal. Accordingly, an efficient multi-step determination of the matrix entries can be implemented. Real values or magnitude values of the matrix entries can be calculated without considering the inter-channel phase difference. Similarly, phase values of the matrix entries can be obtained without considering the inter-channel level difference parameters or inter-channel correlation/coherence parameters, which allows for an optional parallelization of the computations. In addition, the matrix entries can be efficiently adapted such that the inter-channel correlation of the upmixed audio channel signals can be adjusted with good precision.

An embodiment according to the invention creates a method for upmixing a downmix audio signal into an upmixed audio signal.

Another embodiment according to the invention comprises a computer program for performing the functionality of the inventive method.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments according to the invention will subsequently be described taking reference to the enclosed Figs., in which:

FIG. **1** shows a block schematic diagram of an upmixer for upmixing a downmix audio signal into an upmixed audio signal, according to an embodiment of the invention;

FIG. **2** shows a detailed block schematic diagram of an upmixer for upmixing a downmix audio signal into an upmixed audio signal, according to another embodiment of the invention;

FIG. **3***a* shows a flow chart of a method for upmixing a downmix audio signal into an upmixed audio signal, according to an embodiment of the invention;

FIG. **3***b* shows a block schematic diagram of a method for obtaining a set of upmix parameters, according to an embodiment of the invention; and

FIG. **4** shows a block schematic diagram of a conventional generic binaural cue coding scheme.

DETAILED DESCRIPTION OF THE INVENTION

Embodiment According to FIG. **1**

FIG. **1** shows a block schematic diagram of an upmixer **100** according to an embodiment of the invention. FIG. **1** shows the upmixing of a single channel for the sake of simplicity. Naturally, the concept disclosed herein can be applied in multi-channel systems as well, as will be described, for example, with reference to FIG. **2**.

The upmixer **100** is configured to receive a downmix audio signal **110** and to upmix the downmix audio signal **110** into an upmixed audio signal **120** describing one or more upmixed audio channels.

The upmixer comprises a parameter-applier **130**, which is configured to apply upmixing parameters to upmix the downmix audio signal **110** in order to obtain the upmixed audio signal **120**. The parameter-applier **130** is configured to apply a phase shift (shown at reference numeral **140**) to the downmix audio signal **110** to obtain a phase-shifted version **142** of the downmix audio signal **110**, while leaving the decorrelated signal **150** unmodified by the phase shift. The parameter-applier **130** is further configured to combine (shown at reference numeral **160**) the phase-shifted version **142** of the downmix audio signal **110** with the decorrelated signal **150** to obtain the upmixed audio signal **120**.

By applying the phase shift only to the downmix audio signal **110**, but not to the decorrelated signal **150** (which, for example, may be a decorrelated version of the downmix audio signal **110**), the upmixed audio signal **120** comprises a decorrelated portion, wherein the decorrelated portion of the upmixed audio signal **120** is based on the decorrelated signal **150**, and wherein the phase of the decorrelated portion is left unaffected by the phase shift applied to the downmix audio signal **110**. Accordingly, a signal portion of the upmixed audio signal **120** which is correlated with the downmix audio signal **110** is phase-shifted (e.g. in a time-varying manner) in dependence on the applied phase shift, while a portion of the upmixed audio signal **120** which is decorrelated from the downmix audio signal **110** is left unaffected by the phase shift. Accordingly, an adjustment of the inter-channel correlation characteristics of the upmixed audio signal (with respect to further upmixed audio signals) can be performed with high precision without having the requirement to consider the time-varying phase shifts applied to the downmix audio signal.

Embodiment According to FIGS. **2***a* and **2***b*

FIGS. **2***a* and **2***b* show a detailed block schematic diagram of an apparatus **200** according to another embodiment of the invention.

The apparatus **200** is configured to receive a downmix audio signal **210** and to upmix the downmix audio signal **210** into an upmixed audio signal **220**. The upmixed audio signal **220** may, for example, describe a first upmixed audio channel **222***a* and a second upmixed audio channel **222***b*.

The downmix audio signal **210** may, for example, be a sum signal provided by a spatial audio encoder (for example, the sum signal **416** provided by the binaural cue coding encoder **410**). The downmix audio signal **210** may, for example, be represented in the form of a complex-valued frequency decomposition. For example, the downmix audio signal may comprise one sample in every frequency band (out of a plurality of frequency bands) for every audio sample update interval (indicated by temporal index k).

In the following, the processing of samples in one frequency band will be described. However, audio samples in other frequency bands can be processed similarly. In other words, in some embodiments according to the invention, different frequency bands may be processed independently.

Similarly, it is assumed that the first upmixed audio channel signal **222***a* represents, in the form of complex-valued samples, an audio content in a specific frequency band of the upmixed audio signal **220**. Likewise, it is assumed that the second upmixed audio channel signal **222***b* represents, in the form of complex-valued samples, the audio content in the specific frequency band under consideration. Upmixed audio channel signals for different frequency bands may be obtained, however, according to the same concept described herein.

The frequency band processing (i.e. the generation of an upmix signal for a single frequency band) of the apparatus **200** is therefore configured to receive a stream x(k) describing a sequence of subsequent, complex-valued samples of an audio content of the frequency band under consideration. In this notation, k serves as a time index. In the following, x(k) will be briefly designated as "downmix audio signal", keeping in mind that x(k) merely describes the audio content of the single frequency band under consideration of the overall (multi-frequency band) downmix audio signal.

The frequency band processing comprises a decorrelator **230**, which is configured to receive the downmix audio signal x(k) and to provide, on the basis thereof, a decorrelated version q(k) of the downmix audio signal x(k). The decorrelated version q(k) may be represented by a sequence of complex-valued samples. The frequency band processing also comprises a parameter-applier **240**, which is configured to receive the downmix audio signal x(k) and the decorrelated version q(k) of the downmix audio signal and to provide, on the basis thereof, the first upmixed audio channel signal **222***a* and the second upmixed audio channel signal **222***b*.

In the embodiment of FIG. **2**, the parameter-applier **240** comprises a matrix vector multiplier **242** (or any other appropriate means), which is configured to perform a weighted linear combination of the downmix audio signal x(k) and the decorrelated version q(k) of the downmix audio signal to obtain the upmixed audio channel signals **222***a*, **222***b*. The weighting of x(k) and q(k) is determined by entries of a weighting matrix H(k), wherein the entries of the weighting matrix may be time-variant (i.e. dependent from the time index k). In general, some of the entries of the weighting matrix H(k) may be complex-valued, as will be discussed in detail in the following.

In the embodiment of FIG. **2**, a sample $y_1(k)$ of the first upmixed audio channel signal **222***a* may be obtained by adding a sample x(k) of the downmix audio signal, weighted by a complex-valued matrix entry H_{11}, and a temporarily corresponding sample q(k) of the decorrelated signal, weighted with a (typically, but not necessarily, real-valued) matrix entry H_{12}. Similarly, a sample $y_2(k)$ of the second upmixed audio channel signal **222***b* is obtained by adding a sample x(k) of the downmix audio signal, weighted by a complex-valued matrix entry H_{21}, and a temporarily corresponding sample q(k) of the decorrelated signal, weighted with a (typically real-valued) matrix entry H_{22}.

Accordingly, a phase shift or phase rotation is applied to the samples x(k) of the (correlated) downmix audio signal when deriving there-from samples $y_1(k)$, $y_2(k)$ of the upmixed audio channel signals **222***a*, **222***b*. In contrast, the application of a phase shift or phase rotation is avoided when calculating the contribution of the samples q(k) of the decorrelated signal to the samples of the upmixed audio channel signals **222***a*, **222***b*.

In the following, it will be described how the matrix entries H_{11}, H_{12}, H_{21}, H_{22} of the matrix H can be obtained.

For this purpose, the apparatus **200** comprises a side information-processing unit **260**, which is configured to receive a side information **262** describing the upmix parameters. The side information **262** may, for example, comprise spatial cues like, for example, inter-channel level difference parameters, inter-channel correlation or coherence parameters, inter-channel time difference parameters or inter-channel phase

difference parameters. Said parameters ILD, ICC, ITD, IPD are well-known in the art of spatial coding and will not be described in detail here.

The side information-processing unit **260** is configured to provide the (completed) matrix entries H_{11}, H_{12}, H_{21}, H_{22} to the matrix vector multiplier **242** (which is shown at reference numeral **264**). The side information-processing unit **260** can therefore also be considered as a "parameter determinator".

The side information processing unit **260** comprises an upmix parameter real-value determinator **270**, which is configured to receive spatial cues describing an amplitude relationship or power relationship between different signal components in the upmixed audio channel signals **222***a*, **222***b*. For example, the upmix parameter real-value determinator **270** is configured to receive inter-channel level difference parameters and/or inter-channel correlation or coherence parameters. The upmix parameter real-value determinator **270** is configured to provide, on the basis of said spatial cues (e.g. ILD, ICC), real-valued matrix entries. The Upmix parameter real-value determinator **270** is configured to provide the real-valued matrix entries $\tilde{H}_{11}$, $\tilde{H}_{12}$ $\tilde{H}_{21}$, $\tilde{H}_{22}$ on the basis of the received spatial cues (e.g. ILD, ICC). The real-valued matrix entries are designated with **272**. As the computation of the real-valued matrix entries **272** is well-known in the art of spatial decoding, a detailed description will be omitted here. Rather, reference is made to the documents cited under the section entitled "References" and to any other publications well known to the man skilled in the art.

The side information processing unit **260** further comprises an upmix parameter phase-shift-angle determinator **280**, which is configured to receive spatial cues representing a phase shift between different signal components of the upmixed audio channel signals **222***a*, **222***b*. For example, the upmix parameter phase-shift-angle determinator **280** is configured to receive inter-channel phase difference parameters **282**. The Upmix parameter phase-shift-angle determinator **280** is also configured to provide phase-shift-angle values α_1, α_2 associated with the downmix audio signal, which are also designated with **284**. The computation of phase-shift-angle values on the basis of the inter-channel phase difference parameters **282** is well-known in the art, such that a detailed description is omitted here. Reference is made, for example, to the documents cited under section "References", and also to any other publications well-known to the man skilled in the art.

The side information processing unit **260** further comprises a matrix entry rotator **290**, which is configured to receive the real-valued matrix entries **272** and the phase-shift-angle values **284** and to compute, on the basis thereof, the (completed) matrix entries of the matrix H (also designated with H(k) to indicate the time-dependency). For this purpose, the matrix entry rotator **290** may be configured to apply the phase shift angle values α_1, α_2 to those (and, advantageously, only those) real-valued matrix entries **272**, which are intended for application to downmix audio signal x(k). In contrast, the matrix entry rotator **290** is advantageously configured to leave those real-valued matrix entries, which are intended to be applied to samples of decorrelated signal q(k), unaffected by the phase-shift-angle values α_1, α_2. Consequently, those matrix entries, which are intended to be applied (by the matrix-vector multiplier **242**) to samples of the decorrelated signal q(k) remain real values, as provided by the upmix parameter real-value determinator **270**. However, in some embodiments, the inversion of the sign may occur.

In the embodiment shown in FIG. **2**, the following relations may hold:

$$H_{11}=e^{j\alpha_1}\tilde{H}_{11}$$

$$H_{12}=\tilde{H}_{12}$$

$$H_{21}=e^{j\alpha_2}\tilde{H}_{21}$$

$$H_{22}=\tilde{H}_{22}$$

Accordingly, the matrix entry rotator **290** is configured to derive the (completed) matrix entries of the matrix H and to provide these (completed) matrix entries to the matrix-vector multiplier **242**.

As usual, the matrix entries of the matrix H may be updated during the operation of the apparatus **200**. For example, the matrix entries **264** of the matrix H may be updated whenever a new set of side information **262** is received by the apparatus **200**. In other embodiments, interpolation may be performed. Thus, the matrix entries **264** may be updated once per audio sample update interval k in some embodiments wherein an interpolation may be applied.

In the following, the concept according to the present invention which has been described in detail with reference to FIGS. **2***a* and **2***b*, will be briefly summarized. Embodiments according to the invention enhance upmixing techniques by an improved phase processing, which prevents incorrect output inter-channel correlation caused by phase shifting of the decorrelated signal part.

For simplicity, the embodiment shown in FIG. **2** and also the following description restricts to an upmix from one to two channels only. The decoder's upmix procedure from e.g. one to two channels is carried out by a matrix multiplication of a vector consisting of the downmix signal x, called the "dry signal", and a decorrelated version of the downmix signal q, called the "wet signal", with an upmix matrix H. The wet signal q may be generated by feeding the downmix signal x through a decorrelation filter (e.g. in the form of the decorrelator **230**). The output signal y is a vector containing the first and second channel of the output (for example, the first upmix audio channel signal **222***a* and the second upmix audio channel **222***b*).

All signals x, q, y may be available in a complex-valued frequency decomposition. The matrix operation may be performed for all subband samples of every frequency band. The following matrix operation may be performed:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = H \begin{bmatrix} x \\ q \end{bmatrix}$$

The said matrix operation, which may be performed by the matrix-vector multiplier **242**, is also shown in FIG. **2**, wherein the time index k indicates that the input samples x, y, the upmixed output samples y_1, y_2 and also the upmix matrix H are typically time-varying.

The coefficients (or matrix entries) H_{11}, H_{12}, H_{21}, H_{22} of the upmix matrix H are derived from the spatial cues, for example using the side information processing unit **260**. The matrix operation (which is performed by the matrix-vector multiplier **242**) applies a mixing of the dry signal x and the wet signal q according to the ICCs and weighting of the output channels **222***a*, **222***b* according to the ILDs. By using complex-valued coefficients, an additional phase shift according to the IPDs can be applied (as will be described in the following).

The wet signal q is created by passing the downmix signal x through a decorrelation filter (for example, the decorrelator **230**), which is designed in a way that the correlation between x and q is sufficiently close to zero. To recreate the original degree of correlation between the two channels, which is described by the transmitted ICCs, the signals x and q are mixed differently for the two output channels **222***a*, **222***b*. The mixing coefficients (e.g. the matrix entries of the matrix H) are calculated in a way that the correlation of the output channels matches the transmitted ICCs.

The phase relation between the two channels, which is described by the transmitted IPDs, is recreated by applying phase shifts to the output signals. The two signals are generally rotated by different angles.

Conventional decoders apply the phase shifts to the complete output signals, which means that both the dry and wet signal components are processed.

The transmitted IPDs describe the difference of phase angle between the two channels. It has been found that, as no phase difference can be defined for uncorrelated signals, the IPD values are based on the correlated signal components. It has been found that, therefore, it is not necessary to apply the phase rotation to the wet signal part of the output channels. Further, it has been found that the application of different phase shifts to the two channels (comprising the decorrelated signal portions) can even result in a wrong degree of output correlation, as the computation of dry and wet mixing may be based on the assumption that the same decorrelated signal is mixed into both channels.

A common approach for mixing of dry and wet signals is to mix the same amount of wet signal to both channels with different signs. It has been found that, if different phase shifts are applied to the output channels (e.g. after combining the dry signal x and the wet signal q), this out-of-phase property of the wet signal part is destroyed, resulting in a loss of decorrelation.

In contrast, the inventive solution helps to maintain the desired degree of decorrelation.

In the following, further details regarding the embodiment described above will be explained. In an embodiment according to the invention, a modified upmix (when compared to conventional upmix techniques) is used to avoid a loss of decorrelation by this rotation according to inter-channel phase differences (IPDs). As described above, it has been found that a phase shift of the wet signal part can result in a loss of decorrelation and is not necessary for reconstruction of the original phase relation between channels. When applying the phase shift in the upmix matrix H using complex coefficients, the processing can be limited to the dry signal by only rotating those coefficients multiplied with the dry signal.

In the following, a method will be described, which can be used for obtaining the upmix matrix H or upmix parameters (for example, entries of the upmix matrix H).

In a first step, the real-valued matrix $\tilde{H}$ (or the entries thereof) is computed from the transmitted inter-channel level differences (ILDs) and inter-channel correlation or coherence parameters (ICCs), which spatial cues may be received by the apparatus **200** as a part of the side information **262**. This computation (which may be performed by the upmix parameter real-value determinator **270**) may be done in the same way as if no inter-channel phase differences (IPDs) would be used.

In a next step (which may optionally be performed in parallel with the first step, or even before the "first step"), the phase shift angles for the, for example, two output channels α_1 and α_2 are calculated in (for example, in the upmix parameter phase shift angle determinator **280**) from the transmitted IPDs, as usual.

Finally, a complex rotation of those elements (or entries) of the matrix $\tilde{H}$, which are multiplied with the dry signal, i.e. the first column of the matrix, is performed to obtain the upmix matrix H (for example, using the matrix entry rotator **290**):

$$H = \begin{bmatrix} e^{j\alpha_1}\tilde{H}_{11} & \tilde{H}_{12} \\ e^{j\alpha_2}\tilde{H}_{21} & \tilde{H}_{22} \end{bmatrix}$$

Using this modified upmix matrix, phase rotation is only applied to the dry signals part (for example, by the matrix-vector multiplier **242** applying the matrix H), while the wet signal part is not modified and correct decorrelation is preserved.

Method According to FIG. **3***a*

FIG. **3***a* shows a flow chart of a method **300** for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels. The method **300** generally comprises applying **310** upmixing parameters to upmix the downmix audio signal in order to obtain the upmixed audio signal. Applying **310** upmixing parameters comprises a step **320** of applying a phase shift to the downmix audio signal to obtain a phase-shifted version of the downmix audio signal, while leaving a decorrelated signal, unmodified by the phase shift. Applying **310** upmixing parameters further comprises a step **330** of combining the phase-shifted version of the downmix audio signal with the decorrelated signal, to obtain the upmixed audio signal.

It should be noted that the method **300** can be supplemented by any of the functionalities described herein, also with respect to the inventive apparatus.

Method According to FIG. **3***b*

FIG. **3***b* shows a method **350** for obtaining a set of upmix parameters, according to an embodiment of the invention. The method **350** comprises a first step **360** of obtaining real-valued upmix parameters (for example, real-valued matrix entries) describing a desired intensity of contributions of the downmix signal (e.g. the signal x) and of the decorrelated signal (e.g. the signal q) to the upmixed audio channel signals (e.g. y_1, y_2) in dependence on one or more spatial cues (e.g. ILD, ICC) representing the intensity of the contributions. The method **350** further comprises a second step **370** of obtaining phase-shift-angle values (e.g. α_1, α_2) describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals (e.g. y_1, y_2) in dependence on one or more spatial cues representing an inter-channel phase shift (e.g. IPD). The method **350** further comprises a step **380** of rotating (i.e. phase-shifting) real-valued upmix parameters intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters, intended to be applied to the decorrelated signal, unaffected by the phase-shift-angle values, to obtain completed upmix parameters of the set of upmix parameters.

The method **350** can be supplemented by any of the features and functionalities described herein, also with respect to the inventive apparatus.

Computer Program Implementation

Depending on certain implementation requirements, embodiments of the invention can be implemented in hardware or in software. The implementation can be performed

using a digital storage medium, for example a floppy disk, a DVD, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed.

Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed.

Generally, embodiments of the present invention can be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may for example be stored on a machine readable carrier.

Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine readable carrier. In other words, an embodiment of the inventive method is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer.

A further embodiment of the inventive methods is, therefore, a data carrier (or a digital storage medium, or a computer-readable medium) comprising, recorded thereon, the computer program for performing one of the methods described herein.

A further embodiment of the inventive method is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may for example be configured to be transferred via a data communication connection, for example via the Internet.

A further embodiment comprises a processing means, for example a computer, or a programmable logic device, configured to or adapted to perform one of the methods described herein. Al

A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein.

CONCLUSION

To summarize the above, an improved upmixing method for recreating the original inter-channel phase difference while preserving correct decorrelation has been described. Embodiments according to the invention supersede other techniques by preventing a loss of decorrelation in the output signal caused by an undesired phase processing of the decorrelator output.

While this invention has been described in terms of several embodiments, there are alterations, permutations, and equivalents which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and compositions of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations and equivalents as fall within the true spirit and scope of the present invention.

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The invention claimed is:

1. An upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the upmixer comprising:

a parameter applier configured to apply upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal,

wherein the parameter applier is configured to apply a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift, and

to combine the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal;

wherein the upmixer is configured to upmix the downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio channels,

wherein the parameter applier is configured to apply the upmixing parameters to upmix the downmix audio signal using the decorrelated signal in order to achieve a first upmixed audio channel signal and a second upmixed audio channel signal,

wherein the parameter applier is configured to apply a time-variant phase shift to the downmix audio signal to achieve at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other; and

wherein the parameter applier is configured to combine the at least two versions of the downmix audio signal with the decorrelated signal to achieve at least two upmixed audio channel signals such that the decorrelated signal remains unaffected by the time-variant phase shift;

wherein the upmixer is implemented using a hardware apparatus, or using a computer, or using a combination of a hardware apparatus and a computer.

2. The upmixer according to claim **1**, wherein the upmixer is configured to achieve the decorrelated signal such that the decorrelated signal is a decorrelated version of the downmix audio signal.

3. The upmixer according to claim **1**, wherein the parameter applier is configured to combine the at least two versions of the downmix audio signal with the decorrelated signal, such that a signal portion of the first upmixed audio channel signal representing the decorrelated signal and a signal portion of the second upmixed audio channel signal representing the decorrelated signal are in a temporally constant phase relationship.

4. The upmixer according to claim **1**, wherein the parameter applier is configured to combine the at least two versions of the downmix audio signal with the decorrelated signal, such that a signal portion of the first upmixed audio channel signal representing the decorrelated signal and a signal portion of the second upmixed audio channel signal representing the decorrelated signal are in-phase or 180° out-of-phase with respect to each other.

5. The upmixer according to claim **1**, wherein the parameter applier is configured to achieve the at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other before combining the at least two versions of the downmix audio signal with the decorrelated signal, which decorrelated signal is left unaffected by the time-variant phase shift.

6. The upmixer according to claim **1**, wherein the upmixer comprises a parameter determinator configured to determine the phase shift on the basis of an inter-channel phase difference parameter.

7. An upmixer for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the upmixer comprising:

a parameter applier configured to apply upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal,

wherein the parameter applier is configured to apply a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift, and

to combine the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal;

wherein the parameter applier comprises a matrix-vector multiplier configured to multiply an input vector representing one or more samples of the downmix audio signal and one or more samples of the decorrelated signal with a matrix comprising matrix entries representing the upmix parameters to achieve, as a result, an output vector representing one or more samples of a first upmixed audio channel signal and one or more samples of a second upmixed audio channel, and

wherein the upmixer comprises an upmix parameter determinator configured to achieve the matrix entries on the basis of spatial cues associated with the downmix audio signal, and

wherein the upmix parameter determinator is configured to apply a time-variant phase rotation only to matrix entries to be applied to one or more samples of the downmix signal, while leaving a phase of matrix entries to be applied to the one or more samples of the decorrelated signal unaffected by the time-variant phase rotation;

wherein the upmixer is implemented using a hardware apparatus, or using a computer, or using a combination of a hardware apparatus and a computer.

8. The upmixer according to claim **7**, wherein the matrix-vector multiplier is configured to receive the samples of the downmix audio signal and the samples of the decorrelated signal in a complex-valued representation;

wherein the matrix-vector-multiplier is configured to apply complex-valued matrix entries to one or more entries of the input vector in order to apply a phase shift,

to achieve the samples of the upmixed audio channels in a complex-valued representation; and

wherein the upmix parameter determinator is configured to compute real values or magnitude values of the matrix entries on the basis of inter-channel level difference parameters, inter-channel correlation parameters or inter-channel coherence parameters associated with the downmix audio signal,

to compute phase values of matrix entries to be applied to the one or more samples of the downmix signal on the basis of inter-channel phase difference parameters associated with the downmix audio signal, and

to apply a complex rotation to the real values or magnitude values of the matrix entries to be applied to the one or more samples of the downmix signal in dependence on the corresponding phase values to achieve the matrix entries to be applied to the one or more samples of the downmix signal.

9. The upmixer according to claim **7**, wherein the matrix-vector multiplier is configured to achieve the output vector

$$y = \begin{bmatrix} y_1 \\ \vdots \\ y_i \\ \vdots \\ y_N \end{bmatrix}$$

according to the equation

$$y = \begin{bmatrix} e^{j\alpha_1}\tilde{H}_{11} & \tilde{H}_{12} \\ \vdots & \vdots \\ e^{j\alpha_i}\tilde{H}_{i1} & \tilde{H}_{i2} \\ \vdots & \vdots \\ e^{j\alpha_N}\tilde{H}_{N1} & \tilde{H}_{N2} \end{bmatrix} \begin{bmatrix} x \\ q \end{bmatrix}$$

wherein

y_i designates a complex-valued sample of an i-th upmixed audio channel;

α_i designates a phase value associated with the i-th upmixed audio channel;

$\tilde{H}_{i1}$ designates a real-valued magnitude value describing a contribution of the downmix audio signal to the i-th upmixed audio channel;

$\tilde{H}_{i2}$ designates a real-valued magnitude value describing a contribution of the decorrelated signal q to the i-th upmix audio channel;

j designates an imaginary unit;

x designates a sample of the downmix audio signal;

q designates a sample of the decorrelated signal; and

e^{-} designates an exponential function.

10. An apparatus for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio channels, the apparatus comprising:

an upmix parameter real-value determinator configured to achieve real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of a decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contributions;

an upmix-parameter phase-shift-angle determinator configured to achieve one or more phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase difference; and

an upmix parameter rotator configured to rotate real-valued upmix parameters provided by the upmix parameter real-value determinator and intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters provided by the upmix parameter real-value determinator and intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values,

to achieve completed upmix parameters of the set of upmix parameters;

wherein the apparatus is implemented using a hardware apparatus, or using a computer, or using a combination of a hardware apparatus and a computer.

11. The apparatus according to claim 10, wherein the set of upmix parameters is represented by an upmix matrix;

wherein the real-valued upmix parameters are real-valued matrix entries; and

wherein the completed upmix parameters are completed matrix entries; and

wherein the apparatus is configured to achieve the completed upmix parameters such that upmix parameters to be applied to the downmix signal comprise a phase which is dependent on spatial cues received by the apparatus, while upmix parameters to be applied to the decorrelated signal comprise a predetermined phase value which is independent from the spatial cues.

12. A method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the method comprising:

applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal;

wherein applying upmixing parameters comprises applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and

wherein applying the upmixing parameters comprises combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal;

wherein the downmix audio signal is upmixed into an upmixed audio signal describing a plurality of upmixed audio channels,

wherein the upmixing parameters are applied to upmix the downmix audio signal using the decorrelated signal in order to achieve a first upmixed audio channel signal and a second upmixed audio channel signal,

wherein a time-variant phase shift is applied to the downmix audio signal to achieve at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other; and

wherein the at least two versions of the downmix audio signal are combined with the decorrelated signal to achieve at least two upmixed audio channel signals such that the decorrelated signal remains unaffected by the time-variant phase shift.

13. A method for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio signals, the method comprising:

achieving real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of the decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contribution;

achieving phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase difference; and

rotating real-valued upmix parameters intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values,

to achieve completed upmix parameters of the set of upmix parameters.

14. A non-transitory computer readable medium comprising a computer program for performing a method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the method comprising:

applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal;

wherein applying upmixing parameters comprises applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and

wherein applying the upmixing parameters comprises combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal,

wherein the downmix audio signal is upmixed into an upmixed audio signal describing a plurality of upmixed audio channels,

wherein the upmixing parameters are applied to upmix the downmix audio signal using the decorrelated signal in order to achieve a first upmixed audio channel signal and a second upmixed audio channel signal,

wherein a time-variant phase shift is applied to the downmix audio signal to achieve at least two versions of the downmix audio signal comprising a time-variant phase shift with respect to each other; and

wherein the at least two versions of the downmix audio signal are combined with the decorrelated signal to achieve at least two upmixed audio channel signals such that the decorrelated signal remains unaffected by the time-variant phase shift when the computer program runs on a computer.

15. A non-transitory computer readable medium comprising a computer program for performing a method for achieving a set of upmix parameters for upmixing a downmix audio signal into an upmixed audio signal describing a plurality of upmixed audio signals, the method comprising:

achieving real-valued upmix parameters describing a desired intensity of contributions of the downmix signal and of the decorrelated signal to the upmixed audio channel signals in dependence on one or more spatial cues representing the intensity of the contribution;

achieving phase-shift-angle values describing a desired phase shift between downmix audio signal components in different upmixed audio channel signals in dependence on one or more spatial cues representing an inter-channel phase difference; and

rotating real-valued upmix parameters intended to be applied to the downmix audio signal in dependence on the phase-shift-angle values, while leaving real-valued upmix parameters intended to be applied to the decorrelated signal unaffected by the phase-shift-angle values,

to achieve completed upmix parameters of the set of upmix parameters,

when the computer program runs on a computer.

16. A method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the method comprising:

applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal;

wherein applying upmixing parameters comprises applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and

wherein applying the upmixing parameters comprises combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal;

multiplying an input vector representing one or more samples of the downmix audio signal and one or more samples of the decorrelated signal with a matrix comprising matrix entries representing the upmix parameters to achieve, as a result, an output vector representing one or more samples of a first upmixed audio channel signal and one or more samples of a second upmixed audio channel, and

achieving the matrix entries on the basis of spatial cues associated with the downmix audio signal, and

applying a time-variant phase rotation only to matrix entries to be applied to one or more samples of the downmix signal, while leaving a phase of matrix entries to be applied to the one or more samples of the decorrelated signal unaffected by the time-variant phase rotation.

17. A non-transitory computer readable medium comprising a computer program for performing a method for upmixing a downmix audio signal into an upmixed audio signal describing one or more upmixed audio channels, the method comprising:

applying upmixing parameters to upmix the downmix audio signal in order to achieve the upmixed audio signal;

wherein applying upmixing parameters comprises applying a phase shift to the downmix audio signal to achieve a phase-shifted version of the downmix audio signal while leaving a decorrelated signal unmodified by the phase shift; and

wherein applying the upmixing parameters comprises combining the phase-shifted version of the downmix audio signal with the decorrelated signal to achieve the upmixed audio signal,

multiplying an input vector representing one or more samples of the downmix audio signal and one or more samples of the decorrelated signal with a matrix comprising matrix entries representing the upmix parameters to achieve, as a result, an output vector representing one or more samples of a first upmixed audio channel signal and one or more samples of a second upmixed audio channel, and

achieving the matrix entries on the basis of spatial cues associated with the downmix audio signal, and

applying a time-variant phase rotation only to matrix entries to be applied to one or more samples of the downmix signal, while leaving a phase of matrix entries to be applied to the one or more samples of the decorrelated signal unaffected by the time-variant phase rotation

when the computer program runs on a computer.

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